

1.0 Introduction

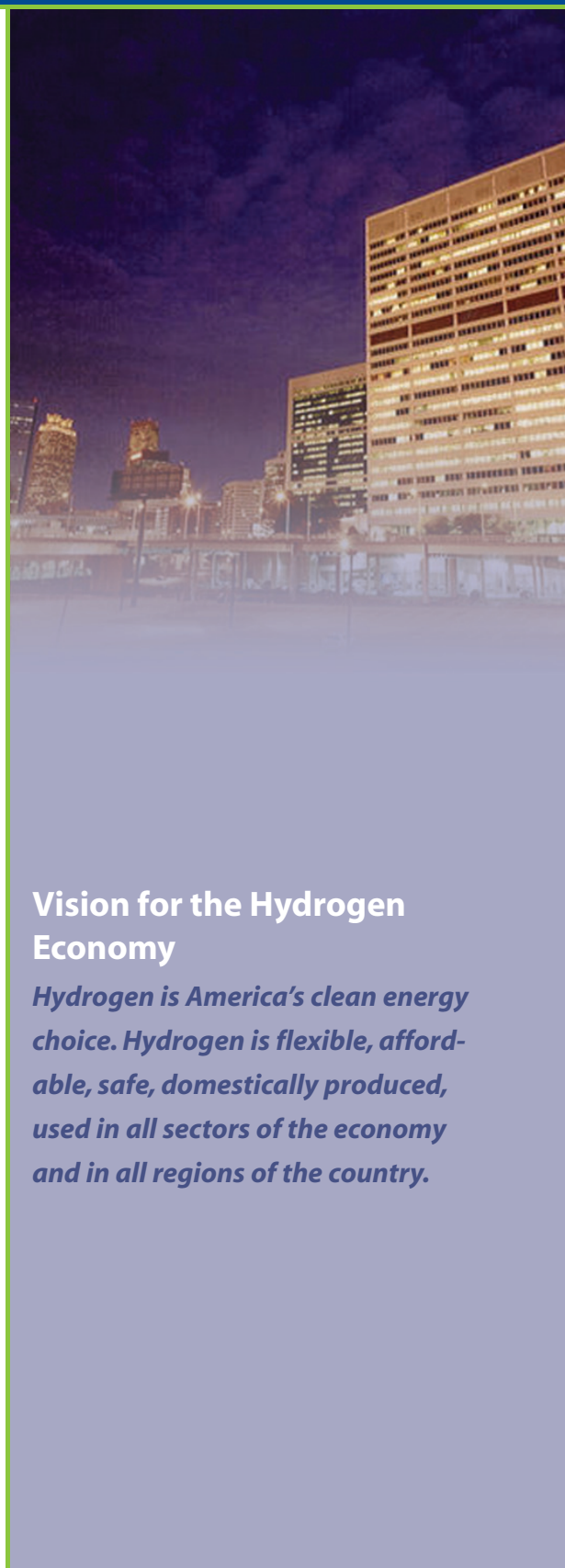
Today, after decades of dependence on imported petroleum to fuel the United States' transportation sector, our nation has a new vision for our future: a form of domestically-derived, clean energy to power not only our vehicles but our industries, buildings, and homes. This form of energy for the future is hydrogen.

President Bush is providing the leadership to help make this vision a reality. In his 2003 State of the Union address, the President proposed the Hydrogen Fuel Initiative to reverse America's growing dependence on foreign oil by developing the technology needed for commercially viable hydrogen-powered fuel cells (see back cover). Through this new initiative and the FreedomCAR Partnership, which was announced in 2002, President Bush has committed \$1.2 billion for the first five years of a long-term research and development effort for hydrogen infrastructure, fuel cells, and hybrid vehicle technologies.

The Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy's (EERE's) Hydrogen, Fuel Cells & Infrastructure Technologies Program is implementing the technology development efforts needed to realize the vision of a hydrogen economy. This Multi-Year Research, Development and Demonstration (RD&D) Plan, covering the period 2003 through 2010, provides a description of the activities that the Hydrogen, Fuel Cells & Infrastructure Technologies Program will undertake to implement the first years of the President's Initiative. The Plan addresses technologies for hydrogen production, delivery, storage and infrastructure; and fuel cells for transportation and stationary applications. As detailed in this Plan, the Nation's best resources will be applied to these RD&D activities, and government resources will be fully leveraged through partnerships with industry as we move toward a hydrogen future.

FreedomCAR and Hydrogen Fuel Initiatives

In January 2002, Secretary of Energy Spencer Abraham announced the FreedomCAR Partnership, a cooperative research effort between DOE and



Vision for the Hydrogen Economy

Hydrogen is America's clean energy choice. Hydrogen is flexible, affordable, safe, domestically produced, used in all sectors of the economy and in all regions of the country.

"This project supports FreedomCAR by providing the means for learning about hydrogen infrastructure technologies necessary for clean energy-efficient vehicles."

Remarks by David K. Garman at the opening of the world's first energy station featuring hydrogen and electricity coproduction, Las Vegas, Nevada, November 15, 2002

USCAR, which is composed of DaimlerChrysler Corporation, Ford Motor Company, and General Motors Corporation. FreedomCAR is based upon the following principles:

- Freedom from petroleum dependence
- Freedom from air pollutant and carbon dioxide emissions
- Freedom for Americans to drive where they want, when they want, in the vehicle of their choice
- Freedom to obtain fuel more affordably and conveniently

FreedomCAR's long-term goal is to develop advanced automotive technologies, which will require no foreign oil and emit no harmful pollutants or greenhouse gases. Specifically, the FreedomCAR Partnership is focusing on developing technologies to enable mass production of affordable hydrogen-powered fuel cell vehicles. In the near-term, FreedomCAR's strategy is to develop hybrid vehicle component technologies (electric motors, power electronics, etc.), which can lead to significant fuel economy improvements through gasoline and hybrid vehicles. These hybrid components are also needed for future fuel cell vehicles.

The President's Hydrogen Fuel Initiative is designed to accelerate development of advanced technologies for producing, delivering, storing, and using hydrogen. This effort puts the development of a hydrogen production and distribution infrastructure on a parallel path in time with development of fuel cell technologies for vehicles. Coupled with FreedomCAR, the Administration has proposed programs that are designed to bring technologies to a point where the private sector can make their business decisions on commercializing fuel cell vehicles by 2015.

1.1 Background

The Hydrogen, Fuel Cells & Infrastructure Technologies Program Multi-Year RD&D Plan represents the details of the technology development, requirements, and schedule called out in the National Energy Policy, the National Hydrogen Energy Vision and Roadmap, and Department of Energy Strategic Plans.



National Energy Policy

The Administration's National Energy Policy, released in May 2001, outlines a long-term strategy for developing and using leading-edge technology within the context of an integrated national energy, environmental, and economic policy. It specifically highlighted the potential of hydrogen with the following recommendations:

- Focus research and development efforts on integrating current programs regarding hydrogen, fuel cells, and distributed energy
- Develop an education campaign that communicates the benefits of alternative forms of energy, including hydrogen.

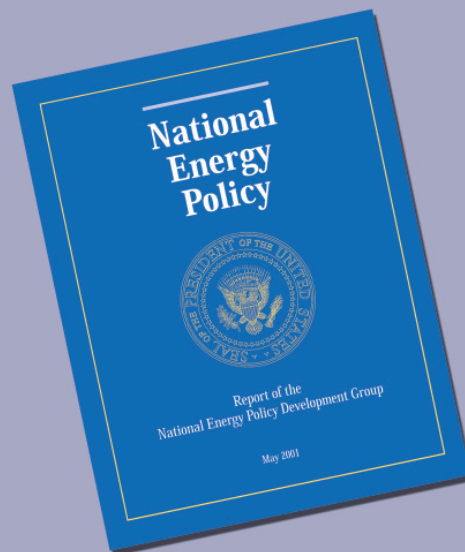
The Administration is recommending and implementing a number of actions that could help reduce our nation's dependence upon imported petroleum in the near-term as hydrogen energy technologies are developed. Among these actions are:

- Promote energy efficiency through research and development of technologies to improve fuel economy (i.e., advanced gasoline/diesel hybrid technology development under FreedomCAR)
- Increase use of renewable and alternative energy with tax credits for purchase of new hybrid fuel cell vehicles between 2002 and 2007
- Reduce petroleum demand by reducing fuel consumption of long-haul trucks by implementing alternatives to idling when parked.

National Hydrogen Energy Vision and Roadmap

In response to recommendations within the National Energy Policy, in November 2001, DOE organized a meeting of 50 visionary business leaders and policy makers to formulate a National Hydrogen Vision. **A National Vision of America's Transition to a Hydrogen Economy—to 2030 and Beyond** was published in February 2002 as a result of the Hydrogen Vision Meeting. This document summarizes the potential role for hydrogen systems in America's energy future, outlining the common vision of the hydrogen economy.

In April 2002, DOE followed up with a larger group of over 200 technical experts from industry, academia, and the National Laboratories to develop a **National**



"The NEPD Group recommends that the President direct the Secretary of Energy to develop next-generation technology-including hydrogen and fusion."

The National Hydrogen Energy Roadmap identifies RD&D priorities to overcome technical barriers in seven areas:

- **Systems Integration**
- **Production**
- **Delivery**
- **Storage**
- **Conversion**
- **Applications**
- **Safety, Codes & Standards**
- **Education**



"And despite the progress of recent decades, we must further address the environmental concerns surrounding the production and use of energy, including those related to transportation, which uses more than two-thirds of the 20 million barrels of oil Americans consume each day."

Energy Secretary Spencer Abraham
14th Annual National
Hydrogen Association Conference,
March 5, 2003

Hydrogen Energy Roadmap. This roadmap, unveiled by Secretary Abraham in November 2002, describes the principal challenges to be overcome and recommends paths forward to achieve our National Vision.

DOE Strategic Plans

Building on the recommendations of the National Energy Policy, and the National Hydrogen Energy Vision and Roadmap, DOE's and EERE's strategic plans provide the broad direction under which this Multi-Year RD&D Plan was formulated.

The **Department of Energy's Strategic Plan** defines how DOE will meet the President's energy goals for the nation. Three of the general goals, i.e., energy resources, environmental quality, and science are supported by strategic objectives that a hydrogen energy system will support.

EERE's Strategic Plan (2002) supports DOE's Strategic Plan. EERE's Plan describes its response to Secretary Abraham's challenge to "leapfrog the status quo" and to pursue "dramatic environmental benefits" in its approach to efficiency and renewable energy technologies. Four strategic goals that are specified in EERE's Strategic Plan and are particularly relevant to the Hydrogen, Fuel Cells & Infrastructure Technologies Program are:

- Dramatically reduce dependence on foreign oil
- Promote the use of diverse, domestic, and sustainable energy resources
- Reduce carbon emissions from energy production and consumption
- Increase the reliability and efficiency of electricity generation

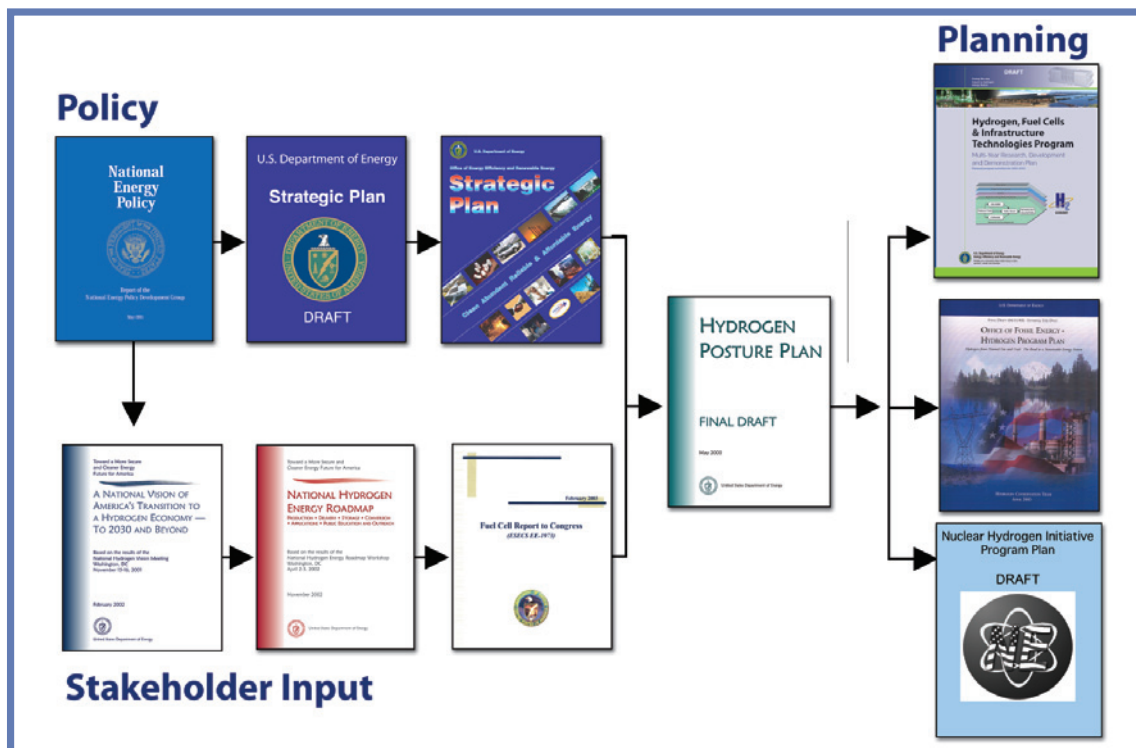
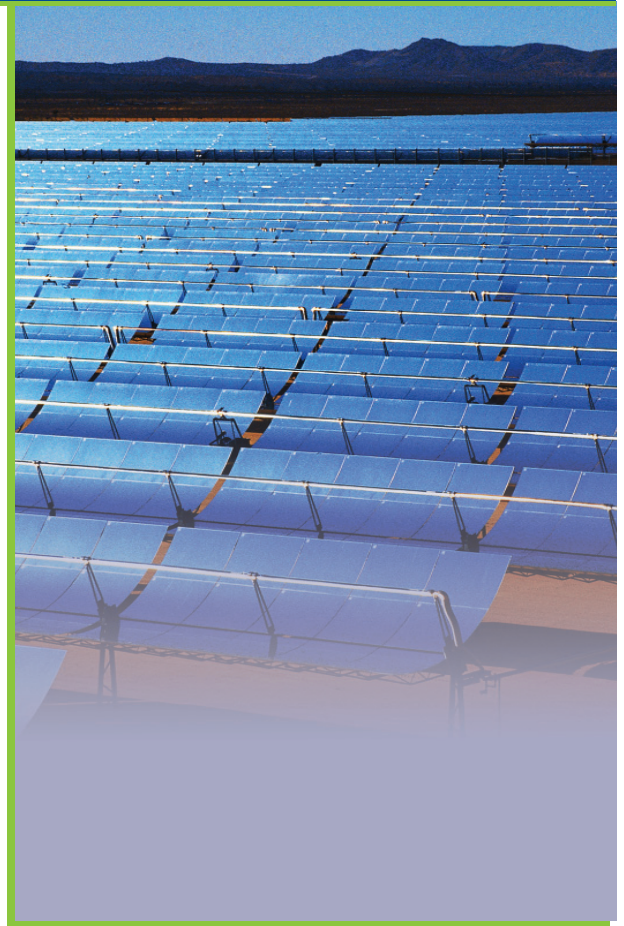
In the Fall of 2002, DOE developed its **Posture Plan**, which describes DOE's "plan for successfully integrating and implementing technology research, development, and demonstration activities needed to cost-effectively produce, store, and distribute hydrogen for use in fuel cell vehicles and electricity generation." Research, development, and demonstration efforts across the DOE Offices of EERE, Nuclear Energy, Science and Technology, Fossil Energy, and Science are described and are consistent with the recommendations in the National Hydrogen Energy Roadmap. The DOE Posture Plan became the key

supporting document used to launch the President's Hydrogen Fuel Initiative.

Another key planning document that provides a framework for this Multi-Year RD&D Plan is **DOE's Fuel Cell Report to Congress** (February 2003). This report summarizes the technical and economic barriers to the use of fuel cells in transportation, portable power, stationary, and distributed power generation applications and provides a preliminary assessment of the need for public-private cooperative programs to demonstrate the use of fuel cells in commercial-scale applications by 2012. Specifically, the report recommends adjusting federally sponsored programs to:

- Focus on advanced materials, manufacturing techniques, and other advancements that will lower costs, increase life and improve reliability for fuel cell systems
- Increase emphasis on hydrogen production and delivery infrastructure, storage, codes and standards development, and education
- Develop public-private cooperative programs, namely, a Stationary and Distributed Generation

Figure 1-4. The Multi-Year RD&D plan is built upon several predecessor planning documents and is integrated with other DOE Office plans



Partnership and a Transportation and Infrastructure Partnership, as a means to overcoming commercialization barriers

DOE hosted workshops with industry stakeholders to gather input for the Fuel Cell Report to Congress.

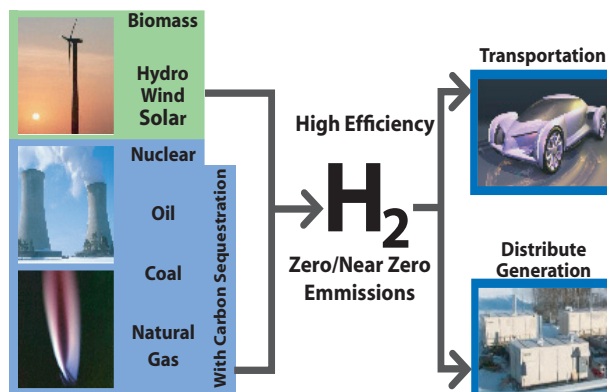
1.2 Hydrogen, Fuel Cells & Infrastructure Technologies Program

The EERE Hydrogen, Fuel Cells & Infrastructure Technologies Program is the lead Federal agency for directing and integrating activities in hydrogen production, storage, and delivery with transportation and stationary fuel cell activities.

It responds to recommendations in the President's National Energy Policy, the National Hydrogen Energy Vision and Roadmap, and DOE Strategic Plans. The program works in partnership with industry, academia, and national laboratories—and in close coordination with the FreedomCAR and Advanced Vehicle Technologies Program and other DOE programs to achieve the four EERE strategic goals that are cited above.

The four EERE strategic goals can be realized with a domestic hydrogen energy system. As illustrated in Figure 1-2, hydrogen can be produced from a diverse set of domestic resources including fossil, nuclear, and renewable resources helping to attain the first three strategic goals. High efficiency and low emissions through use of fuel cells in both transportation and distributed electric power generation help attain the last two strategic goals.

Figure 1-2. A domestic hydrogen energy system will help DOE's EERE meet four strategic goals.

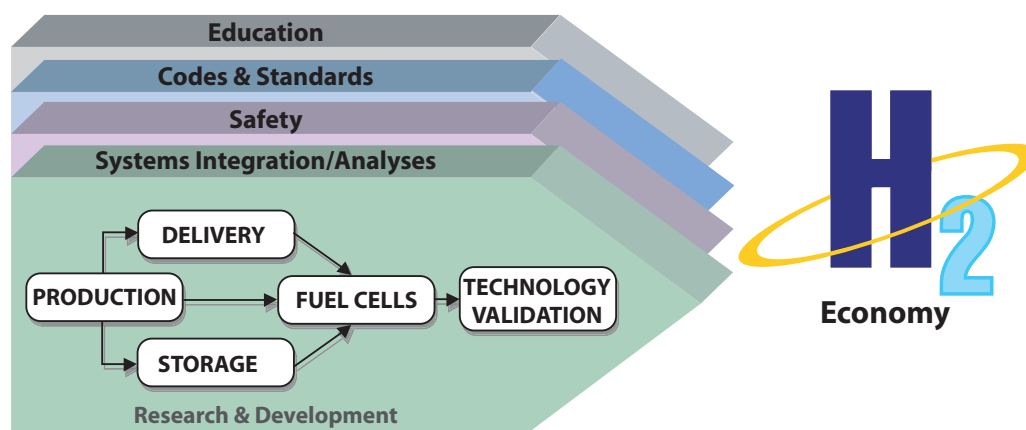


The mission of the Hydrogen, Fuel Cells & Infrastructure Technologies Program is to research, develop, and validate fuel cell and hydrogen production, delivery, and storage technologies for transportation and stationary applications.

Program Elements

The program conducts its research, development, and validation activities through nine key program components. The detailed technical targets and milestones that have been identified for each element are identified in this RD&D Plan.

Figure 1-3. The Hydrogen, Fuel Cells & Infrastructure Technologies Program is being conducted with nine interrelated elements.



| | |
|------------------------------|--|
| Production | Production of hydrogen from domestic resources minimizing environmental impacts |
| Delivery | Distribution of hydrogen from centralized or from distributed sites of production |
| Storage | Storage of hydrogen (or its precursors) on vehicles or within the distribution system |
| Fuel Cells | Conversion of hydrogen to electrical or thermal power; use of hydrogen to power vehicles (primary propulsion), for auxiliary power units for vehicles, and stationary and portable applications |
| Technology Validation | Technical validation of systems in real-world environments |
| Safety | Safety assurance in DOE-sponsored R&D activities and in the marketplace |
| Codes and Standards | Development of model codes and standards for domestic and international production, distribution, storage and utilization of hydrogen |
| Education | Education of key target audiences—including teachers and students, state and local governments, safety and code officials, large-scale end users, and the public—about the hydrogen economy and how it can affect them |
| Systems Integration | Understanding the complex interactions between components, systems costs, energy efficiency, environmental impacts, societal impacts and system trade-offs |

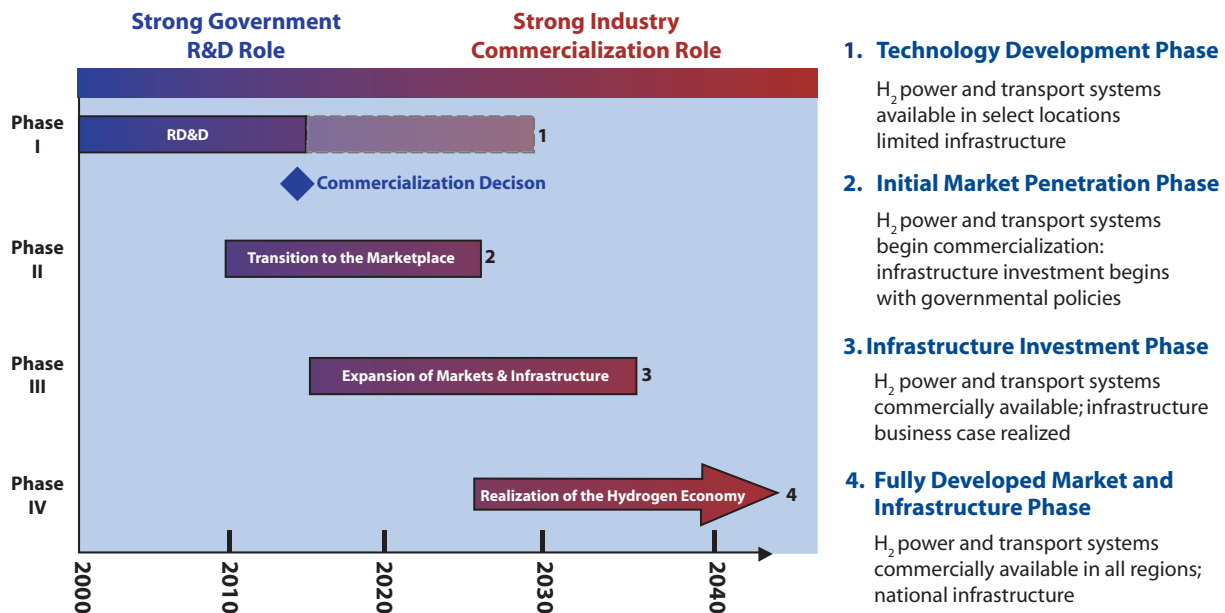


Government and Industry Roles in Developing Hydrogen Technologies

The Hydrogen, Fuel Cells & Infrastructure Technologies Program funds research, development, and validation activities linked to public-private partnerships. The government's current role is to concentrate its funding on high-risk, pre-competitive research in the early phases of development. As activities progress through the stages of developing technology to validating technical targets, the government's cost share will diminish. The government's role as co-funder will bring technologies to the point where the private sector can make informed decisions on whether or not, and how best to commercialize technologies.

DOE envisions four phases in the transition to a hydrogen economy, each of which requires and builds on the success of its predecessor. The bulk of the work for each phase will take place in the timeframe indicated in Figure 1-4; in addition, the work in progress will continue on as the next phase begins. The transition to a hydrogen economy will take several decades, and this transition will

Figure 1-4. The timeframe is long and the investment is large to attain self-reliance in meeting our Nation's energy needs while minimizing environmental impacts.



require strong public and private partnerships, commitment, and resolve.

In Phase I, government and private organizations will research, develop, and demonstrate “critical path” technologies and work to establish comprehensive safety guidelines and codes and standards prior to investing heavily in infrastructure. This phase is now underway, and it will enable industry to make decisions on commercialization by 2015. Following a positive commercialization decision, research will continue on advanced technologies for hydrogen production. Throughout the RD&D phase, exploratory research in materials sciences and engineering, chemistry, geosciences, and molecular biosciences, will be carried out in close collaboration with the DOE Office of Science.

Phase II is the Initial Market Penetration Phase. This could begin as early as 2010 for applications such as portable power and some stationary applications and continue as hydrogen-related technologies meet or exceed customer requirements.

As these markets become established, government can foster their further growth by playing the role of “early adopter,” and by creating policies that stimulate the markets. As markets are established, this leads to Phase III, the Infrastructure Investment Phase, in which there is expansion of markets and infrastructure. The start of Phase III is consistent with a positive commercialization decision for fuel cell vehicles in 2015. A positive decision will attract investment in infrastructure for manufacturing fuel cells and for producing and distributing hydrogen. Government policies still may be required to nurture this infrastructure expansion phase.

Phase IV, which could begin around 2025, is the Fully Developed Market and Infrastructure Phase. In this phase, consumer requirements will be met or exceeded, national benefits in terms of energy security and improved environmental quality will be achieved, and industry will receive adequate return on investment and compete globally. Phase IV provides the transition to a full hydrogen economy by 2040.

Phase I will not abruptly end if industry makes a positive commercialization decision in 2015.

“And despite the progress of recent decades, we must further address the environmental concerns surrounding the production and use of energy, including those related to transportation, which uses more than two-thirds of the 20 million barrels of oil Americans consume each day.”

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Introduction



Promoting the use of diverse, domestic, and sustainable energy resources will dramatically reduce dependence on foreign oil.

Just as the Department still conducts research and underlying science for internal combustion engines today, the dotted lines in Figure 1-4 symbolize continued research. This research will be more fundamental in nature, and will be focused more on long-term pathways, such as photolytic production of hydrogen.

1.3 Scope of Multi-Year RD&D Plan

This Multi-Year RD&D Plan presents tasks and milestones for an eight-year period, and thus, represents a snapshot in time of the DOE's Hydrogen, Fuel Cells & Infrastructure Technologies Program, which is focused on longer-range objectives. Planned activities are focused on technologies for hydrogen production, delivery, and storage; fuel cells for transportation and stationary applications; technology validation; codes and standards; safety; education; and systems integration. For each of these program elements, goals and objectives are identified through 2015, and technical targets, milestones, and schedules are identified for the years 2003 through 2010. While the government's role is key to advancing hydrogen and fuel cell research and technologies in the early stages of development, once the technical targets are validated in a systems context, government's role ends and industry takes over commercialization of the technologies. To keep moving efficiently toward the goal of commercialization, the plan will be updated periodically to reflect advances in technology, changes to and within the system, and policy decisions.